EDITED BY BILL TRAVIS & ANNE WATSON SWAGER

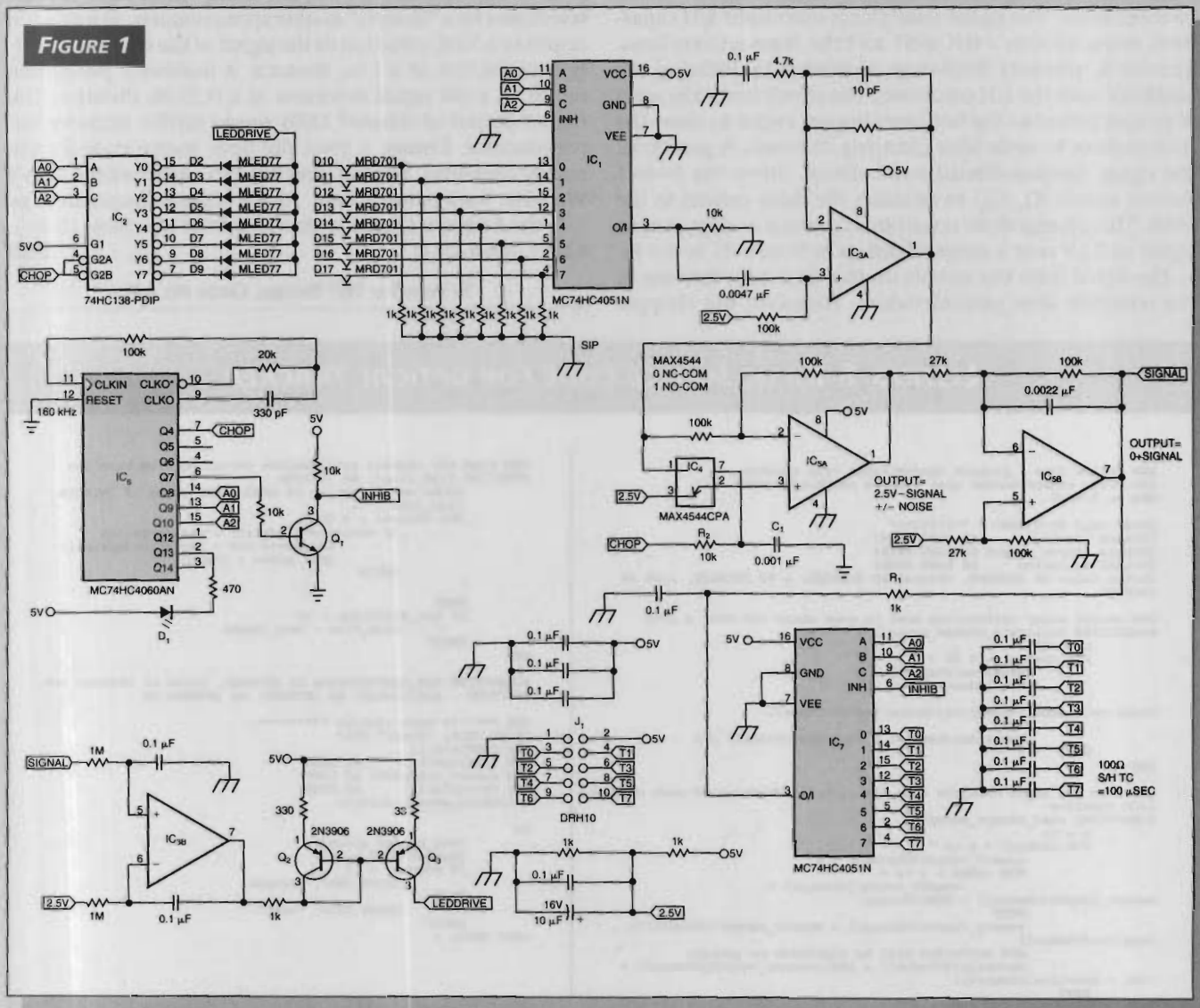
Demodulator makes low-cost optical tracker

STEVEN SARNS, KESTA TECHNOLOGY INC, WHEAT RIDGE, CO

A project required building a synchronous-demodulator circuit to track a line drawn on paper. The beauty of the synchronous-modulator/demodulator approach is its inherent noise rejection. The method rejects nearly all out-of-band noise, whether from internal drift or external illumination. This rejection is a boon in optical tracking, where the return signal is inevitably buried in 120-Hz ambient light, amplifier offsets, and temperature drifts. The circuit in **Figure 1** is inexpensive, and it operates from 5V dc. The circuit scans eight LED/sensor pairs every 22 msec and stores the result in eight sample/hold (S/H) capacitors for interrogation by a µP-driven ADC. The purpose of the circuit is to determine which sensor is above the line.

The 74HC4060 generates a chopper signal at a rate of 3 kHz. Every eight chopper cycles, the circuit increments the three address lines, thereby selecting the LED to illuminate through the 74HC138 multiplexer. The chopper signal gates the 138 on and off, thus producing the synchronous modulation of the signal at the selected LED. A 74HC051 demultiplexes the received signal from the sensor array, using the three address lines. A 2.5V rail is the signal reference for the next two stages of amplification to produce maximum signal

FIGURE 1



Synchronous modulation and demodulation yield an optical line tracker with high immunity to ambient-light noise and temperature and component drifts.

swing. The signal ac-couples to a gain stage, set nominally at a gain of 20. Two poles of lowpass filtering provide first-order 120-Hz rejection.

The next amplifier switches between gains of 1 and –1. This switching is the heart of the synchronous demodulator. If no noise were present with the incoming signal, the output would appear as a dc level equal to one-half the incoming peak-to-peak signal. The circuit asynchronously amplifies any noise appearing on the incoming signal, such that the output of the demodulator swings above and below the expected dc level by the amount of the noise. The next stage of amplification averages out this noise signal. The third stage of amplification averages the demodulator's output and references the result to ground, such that an increasing return signal produces an increasing output.

A gain of four allows the output signal to approach 4V, while still providing the demodulator stage enough overhead to reject noise. The signal multiplexes onto eight S/H capacitors, using another 74HC4051 and the three address lines. Resistor R_1 prevents third-stage oscillation by isolating the amplifier from the S/H capacitors. The circuit limits the actual sample period to the last four chopper cycles to allow the demodulator to settle after changing channels. A portion of the signal, lowpass-filtered and buffered, drives the 10-to-1 current mirror (Q_1, Q_2) to establish the drive current to the LEDs. This arrangement results in a constant average output signal of 2.5V over a range of distances from 0.05 to 0.5 in.

The signal from the sensors undergoes a delay because of the relatively slow photodetectors. Therefore, the chopper signal must also have a delay (via R_2C_1) before controlling the ±1 gain switch, so the phase matches as closely as possible. Select the appropriate delay to minimize the carrier-frequency noise on the output signal. You can use low-cost components throughout. Suitable choices include an LM358AN for IC_3 and a CA3260 for IC_5. You should use CMOS op amps because of the high resistance values in the circuit. The second stage should have rail-to-rail output capability to reject noise effectively. Amplifier saturation appears on the output as noise.

Amplifier speed is not of great concern, because the phototransistors are the slowest components in the processing path. Individual sensors vary from unit to unit. You can select the eight emitter resistors to produce matching outputs, if desired. You can place the eight LEDs along the edge of the pc board on the solder side, and the eight sensors on the component side, spaced 0.2 in. apart. Using visible-light LEDs, a line drawn by a "Sharpie" marker approximately 30 mils wide results in a 50% reduction of the signal of the channel directly over the line at a 1-in. distance. A number-2 pencil line results in a 5% signal reduction at a 0.25-in. distance. The higher output of infrared LEDs would further improve the performance. **Listing 1** gives the Basic source code for the tracker operation. You can download the routine from *EDN*'s Web site, www.ednmag.com. At the registered-user area, go into the Software Center to download the files from DI-SIG, #2211. (DI #2211) EDN

To Vote For This Design, Circle No. 465

LISTING 1–BASIC SOURCE CODE FOR OPTICAL TRACKER

```
REM Follow line - program demonstrates line tracker
REM print sensor number that line is currently under
REM ss 2/9/98

CONST CRLF AS STRING = "\013\010"
DECLARE baseline      AS LONG ARRAY
DECLARE sensor_output AS LONG ARRAY
DECLARE deviation     AS LONG ARRAY
GLOBAL index AS INTEGER, channel AS INTEGER, n AS INTEGER, lost AS
INTEGER

REM sensor array calibration must be done while not over a line
SUBROUTINE calibrate_sensor_array()
        n = 100
        FOR channel = 0 TO 7
                baseline[channel] = 0
                FOR index=1 TO n

baseline[channel]=baseline[channel]+AIN(channel)
                NEXT
                baseline[channel] = baseline[channel] / n
        NEXT
END

REM read all input channels into array, calc deviation of each channel
from baseline
SUBROUTINE read_sensor_array()
        n = 10
        FOR channel = 0 to 7
                sensor_output[channel] = 0
                FOR index = 1 to n
                        sensor_output[channel] =
sensor_output[channel] + AIN(channel)
                NEXT
                sensor_output[channel] = sensor_output[channel]/n -
baseline[channel]
                REM deviation will be expressed as percent
                deviation[channel] = ABS((sensor_output[channel] *
100) / baseline[channel])
        NEXT
END
```

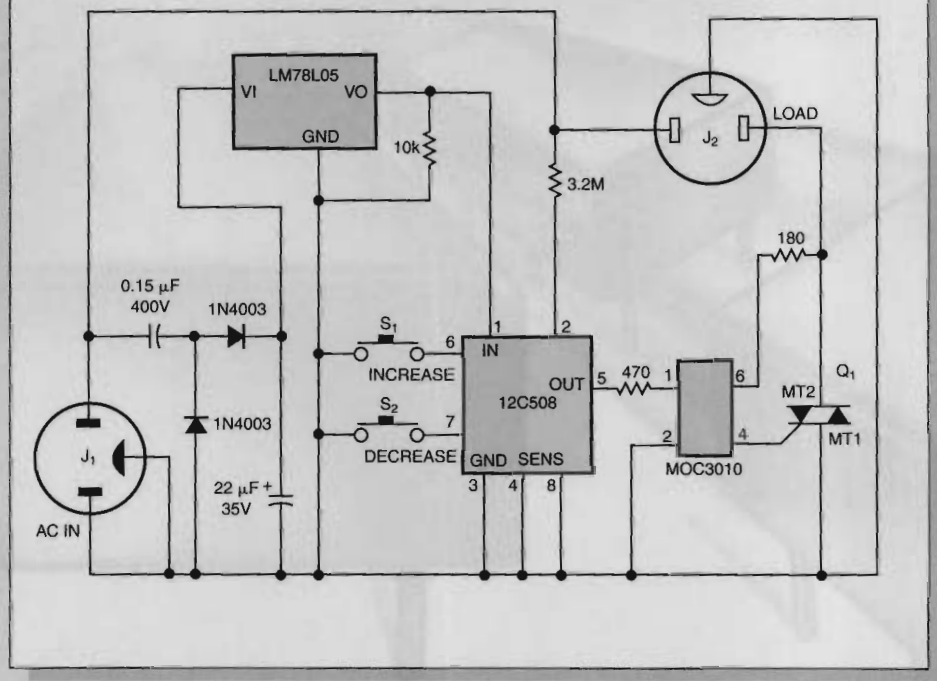
```
REM find the channel with maximum deviation from baseline
FUNCTION find_line() AS INTEGER
        LOCAL max_deviation AS LONG, best_guess AS INTEGER
        find_line = -1
        FOR channel = 0 TO 7
                IF deviation[channel] > max_deviation
                        max_deviation = deviation[channel]
                        best_guess = channel
                ENDIF

        NEXT
        IF max_deviation > 15
                find_line = best_guess
        ENDIF
END

SUBROUTINE AIN_CONFIG(vmode AS INTEGER, value AS INTEGER):49
FUNCTION   AIN(channel AS INTEGER) AS INTEGER:48

REM ******* main routine *********
PRINT CRLF, "Start",CRLF
AIN_CONFIG(0,1)
DIM baseline[8]      AS LONG
DIM sensor_output[8] AS LONG
DIM deviation[8]     AS LONG
calibrate_sensor_array()

DO
        read_sensor_array()
        channel=find_line()
        IF channel > -1
                PRINT CRLF, channel
        ELSE
                PRINT CRLF, "Lost"
        ENDIF
LOOP UNTIL 0
```

µC implements pushbutton light dimmer

WILLIAM GRILL, RIVERHEAD SYSTEMS, LITTLETON, CO

Using a 12C508 Microchip µC, as described in the *EDN*, Dec 18, 1997, Design Idea, "Controller provides multimode phase control," you can implement an inexpensive dimmer control to provide constant-power control of a line-powered load (**Figure 1**). The previously described controller evaluated an input frequency relative to its local time reference and scaled a tabled phase offset to define the specific phase-step timing relative to the zero crossings of the monitored input. A two-button, debounced counter provided manual indexing of the tabled offset table. The table used 5° steps. Redefinition of the table allowed nonlinear phase indexing to accommodate specific requirements, including constant power or luminescence profiles. The code, usable from 1 Hz to 1 kHz, accommodated common 60-Hz line-power applications, such as the one described here.

FIGURE 1

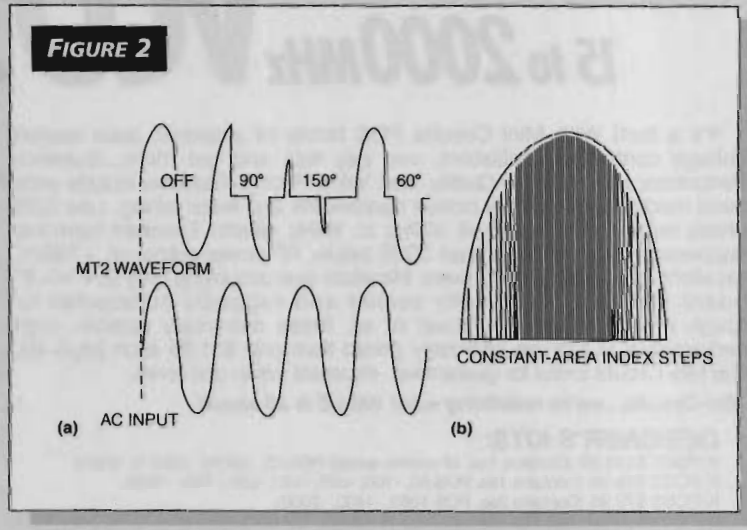


This inexpensive, µC-controlled pushbutton light dimmer operates directly from the ac line.

You can connect the 12C508 controller in **Figure 1** directly to the ac line by limiting the line pin's input current to a few microamperes. The combination of the 3.2-MΩ resistor and the use of the µC's internal diode in pin 2 allows monitoring the ac line with only a small phase error. A simple power converter and an inexpensive LM78L05 linear regulator provide the V_{DD} supply to the µC directly from the ac power line. With the controller-mode and sense pins 3 and 4 grounded, the processed output pulse couples directly to the triac, Q_1, using an optically coupled MOC3010 diac. In **Figure 2a**, the typical output waveform references to MT2 of the triac. This application modifies the phase table to provide a 78-step index, calculated to provide constant power. Thus, the areas under the curve are approximately the same for all steps (**Figure 2b**). You can download the µC code for this application from *EDN*'s Web site, www.ednmag.com. At the registered-user area, go into the Software Center to download the files from DI-SIG, #2212. (DI #2212)

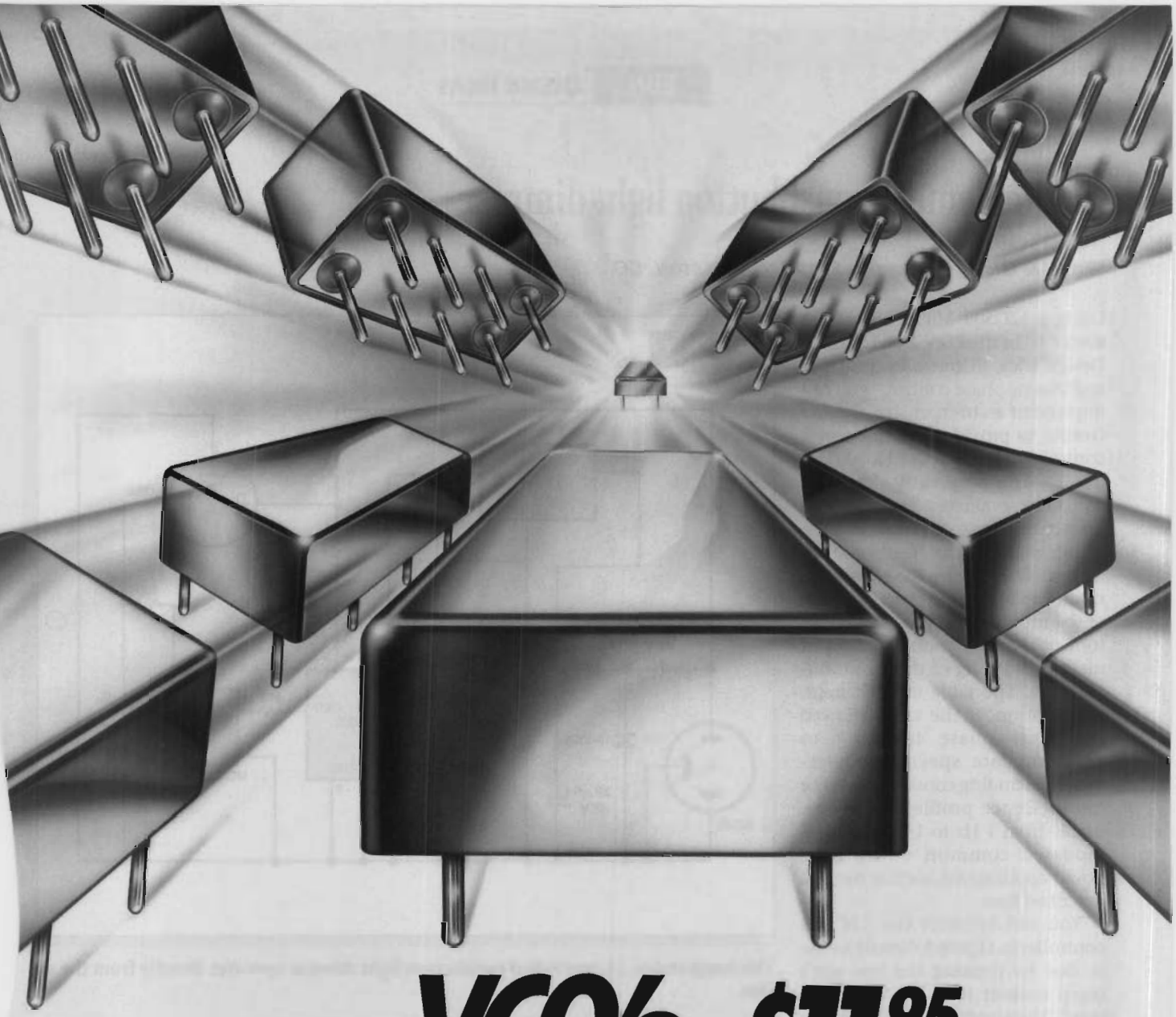
EDN

FIGURE 2



The µC in Figure 1 controls a diac/triac combination to provide phase control (a) in a light-dimming application. A 78-step index in the phase table provides constant-power steps (b).

To Vote For This Design, Circle No. 466



15 to 2000MHz VCO's from $11.95 (5-49)

It's a fact! With Mini-Circuits POS family of shielded, laser sealed voltage controlled oscillators, you pay less and get more...Superior Performance, Top Notch Quality, and Value Pricing. Features include wide band models with typically octave bandwidths and linear tuning. Low SSB phase noise characterized at 100Hz to 1MHz offsets. Excellent harmonic suppression typically more than 30dB below. RF power output of +7dBm, excellent for driving level 7 mixers. Miniature size occupying only 0.4"x0.8" board space. Hermetically sealed and ruggedly constructed for tough environments. And best of all, these extremely reliable, high performance VCO's are affordably priced from only $11.95 each (qty.5-49). Call Mini-Circuits today for guaranteed shipment within one week.

Mini-Circuits...we're redefining what VALUE is all about!

DESIGNER'S KITS:

K-POS1 $124.95 (Contains 1ea. all models except POS-25, -900W, -1060 to -2000).
K-POS2 $79.95 (Contains 1ea. POS-50, -100, -200, -400, -535, -765, -1025).
K-POS3 $79.95 (Contains 2ea. POS-1060, -1400, -2000).

Model	Freq. Range (MHz)	Phase Noise (dBc/Hz) SSB @10kHz Typ.	Harmonics (dBc) Typ.	Current (mA) @ +12V DC Max.	Price (Qty.5-49) $ ea.
NEW POS-25	15-25	-105	-28	20	16.95
POS-50	25-50	-110	-19	20	11.95
POS-75	37.5-75	-110	-27	20	11.95
POS-100	50-100	-107	-23	20	11.95
POS-150	75-150	-103	-23	20	11.95
POS-200	100-200	-102	-24	20	11.95
POS-300	150-280	-100	-30	20	13.95
POS-400	200-380	-98	-28	20	13.95
POS-535	300-525	-98	-26	20	13.95
POS-765	485-765	-85	-21	22	14.95
NEW POS-900W	500-900	-105	-26	25	16.95
NEW POS-1000W	500-1000	-90	-26	20	19.95
POS-1025	685-1382.5	-84	-23	22	16.95
POS-1060	750-1060	-90	-11	30*	14.95
POS-1400	975-1400	-95	-11	30*	14.95
POS-2000	1370-2000	-95	-11	30*	14.95

*Max. Current (mA) @ 8V DC.
Notes: Tuning voltage 1 to 16V required to cover freq. range. 1 to 11V for POS-25, 1 to 20V for POS-1060 to -2000. 3dB modulation bandwidth for POS-25 is 60kHz, POS-50 to -1025 is 100kHz, and POS-1060 to -2000 is 2MHz (all typ.). Operating temperature range: -55°C to +85°C. 5V tuning models available. Consult RF/IF Designer's Guide or call Mini-Circuits.

Mini-Circuits®

US 68

CIRCLE READER SERVICE CARD

P.O Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718)332-4661 ***INTERNET*** http://www.minicircuits.com
For detailed specs on all Mini-Circuits products refer to • 760-pg. HANDBOOK • MICROWAVE PRODUCT DATA DIRECTORY • EEM

ISO 9001 CERTIFIED

F 229 Rev B

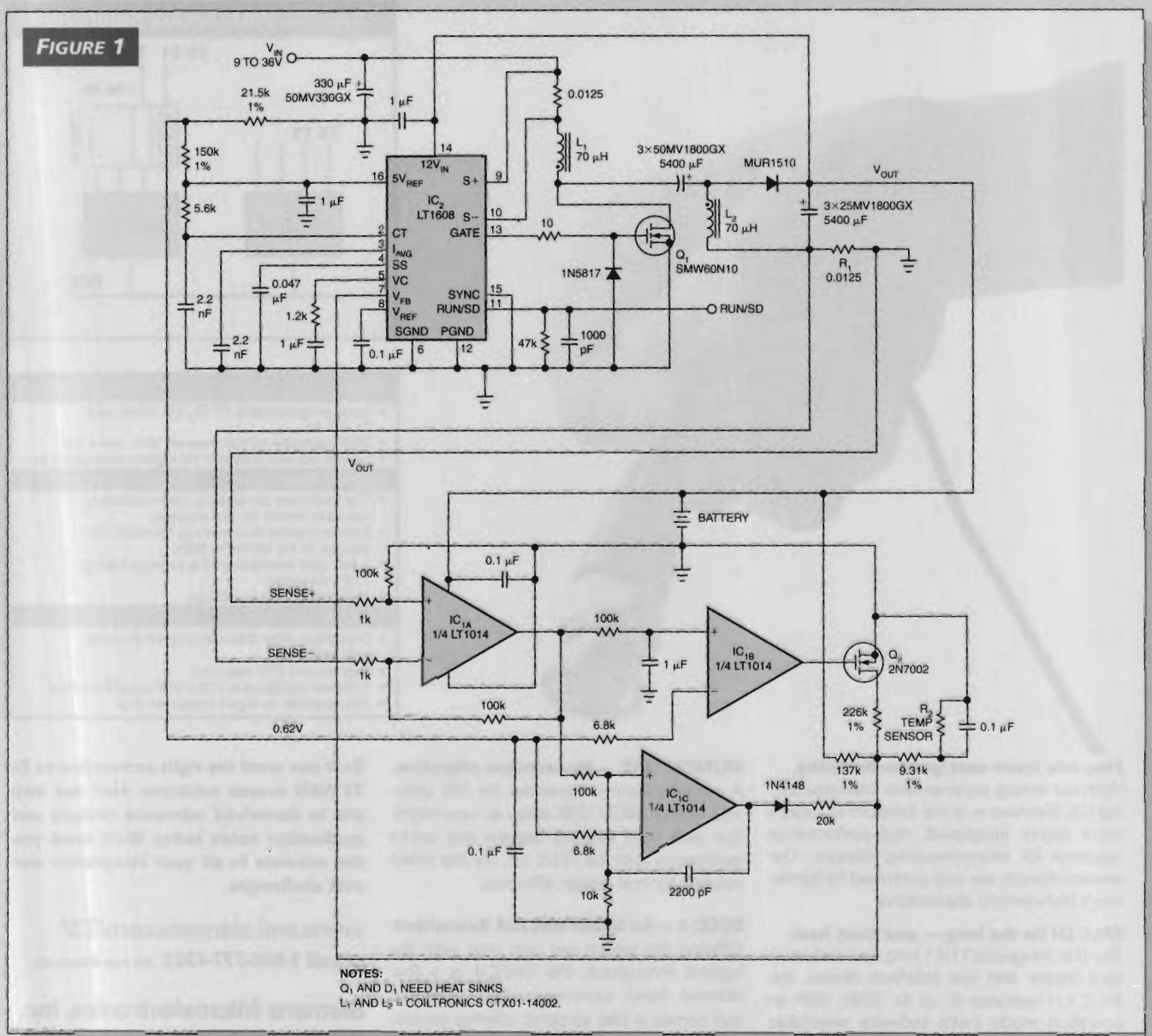
Charger selects between full and trickle charge

AJMAL GODIL, LINEAR TECHNOLOGY CORP, MILPITAS, CA

The circuit in **Figure 1** charges a lead-acid battery at full charge voltage while monitoring the charge current. When the charge current decays to approximately 0.1C, where C is the capacity of the battery, the charger automatically switches to a lower trickle-charge voltage. The battery can remain in this state for a long time, minimizing any degradation of battery life.

The most common method for charging sealed lead-acid batteries is constant-voltage charging, which means that the charger voltage is uniform, regardless of the state of the battery. When the battery is fully discharged, its voltage is less than the charge voltage and the current flow into the battery is large. As the battery charges, its voltage increases, and the charge current decreases. Although the current of a constant-voltage charger starts out high, it decays exponentially. Because of this exponential decay, you can potentially over-

FIGURE 1



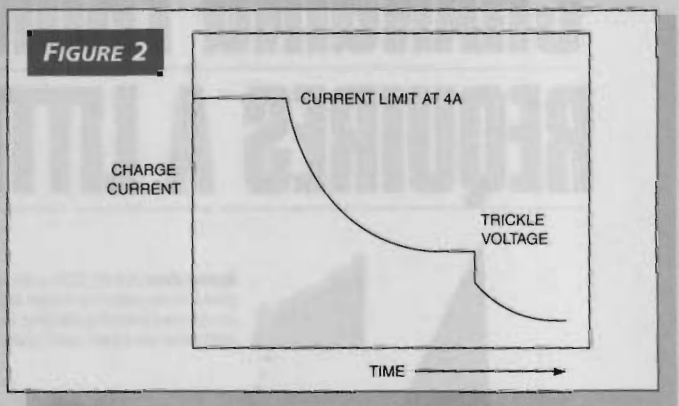
NOTES:
Q_1 AND D_1 NEED HEAT SINKS.
L_1 AND L_2 = COILTRONICS CTX01-14002.

This sealed lead-acid-battery charger monitors the charge current and switches to a trickle-charge voltage of 16.45V when the charge current drops below 0.5A.

charge the battery using a fast-charging scheme. However, the charger in **Figure 1** avoids overcharging by always monitoring the charge current.

The 75W sealed lead-acid battery charger for seven tall D cells in **Figure 1** uses a high-power, current-mode switching regulator (IC_2). The required full-charge voltage is 2.45V/cell, and the trickle-charge voltage is 2.35V/cell. Discharged batteries can draw as much as 16A of charge current because they have low internal resistance. The charger circuit is current-limited at 4A. This current limit is equivalent to 1C, which is the maximum current into the battery and the charger's safe limit.

When you plug a discharged battery into the charger, the battery attempts to draw as much as 16A. Because the charger is current-limited, it delivers only about 4A, and the battery voltage starts rising. When the charge current drops below 4A, IC_2's internal feedback loop takes over and regulates to a charging voltage of 17.15V. As the battery charges, it draws less and less charge current (**Figure 2**). When the charge current decays to 0.5A (0.125C), it produces a voltage drop of 6.25 mV across R_1. IC_{1A} amplifies this voltage by 100, which trips comparator IC_{1B} and turns off Q_2. This action lowers the feedback resistance and sets the lower trickle-charge voltage to 16.45V. The charge current continues to fall as the battery charges. Additionally, the circuit automatically adjusts the charge voltage as a function of temperature by using R_2, a silicon temperature sensor, to give a –3 mV/°C temperature coefficient. (DI #2203) EDN



When first charging a fully discharged battery, the charger delivers 4A, which is the current limit. As the battery continues to charge, the charge current decays exponentially. When the charge current falls to 0.5A, the charger switches to a trickle charge

To Vote For This Design, Circle No. 467

Power supply runs off battery or wall adapter

DAVID BELL, LINEAR TECHNOLOGY CORP, MILPITAS, CA

Most portable products need to operate from both a battery and an external wall adapter. Although conceptually simple, implementing a robust and bulletproof design that properly switches between these two power sources can be challenging. The circuit in **Figure 1a** delivers 5V at 50 mA from four AAA alkaline cells or from a 6V wall adapter, which is enough power for many handheld applications. This circuit meets the following design criteria:

- Step-up/step-down dc/dc conversion: Delivering 5V from four alkaline cells—a range of 6.2 to 3.2V—or from a 6V wall adapter means that the converter must be capable of stepping up or down to deliver a regulated 5V output.
- Reverse-battery protection: When using individual batteries, the power supply should be able to tolerate reverse-battery insertion. This circuit is undamaged, even when someone installs all four cells backward.
- Reverse-wall-adapter protection: Wall adapters come in many flavors and both connector polarities. As with reverse batteries, reversing the voltage applied to the wall-adapter input does not damage this power supply.
- Battery operation to 100% discharge: Alkaline batteries deliver their rated capacity only if they discharge all the way down to 0.8V/cell. This power supply can deliver full-rated current to as low as 0.8V/cell, with four alkaline cells in series.
- Battery reverse-current prevention: Reverse charging current can result in electrolyte leakage from normal alkaline cells. The design must never allow reverse battery current to flow when the wall adapter is connected.
- Very low battery current drain when off: The design must minimize off-state current drain to sustain battery capacity when the product is off. This circuit draws only 25 µA when shut down, which is only slightly more than a AAA battery's self-discharge current.
- Clean switch-over between battery and wall adapter: Many products, even some expensive notebook computers, momentarily lose regulation when switching between a battery and a wall adapter. This power supply maintains output regulation when you insert or remove the wall adapter and operates from the wall adapter without batteries installed.
- Battery-drain prevention even with an inserted wall adapter: Surprising as this fact may seem, some products continue to drain the battery if the wall-adapter voltage is slightly less than the battery voltage, which is possible with fresh cells. This circuit operates from the wall adapter if its voltage is greater than 4.5V, even if the battery voltage is higher.

The heart of the circuit is IC_1, a charge-pump dc/dc converter. This converter is capable of step-up or -down operation over a 3.2 to 10V input range. The IC uses no inductors and requires only one external charge-pump capacitor for

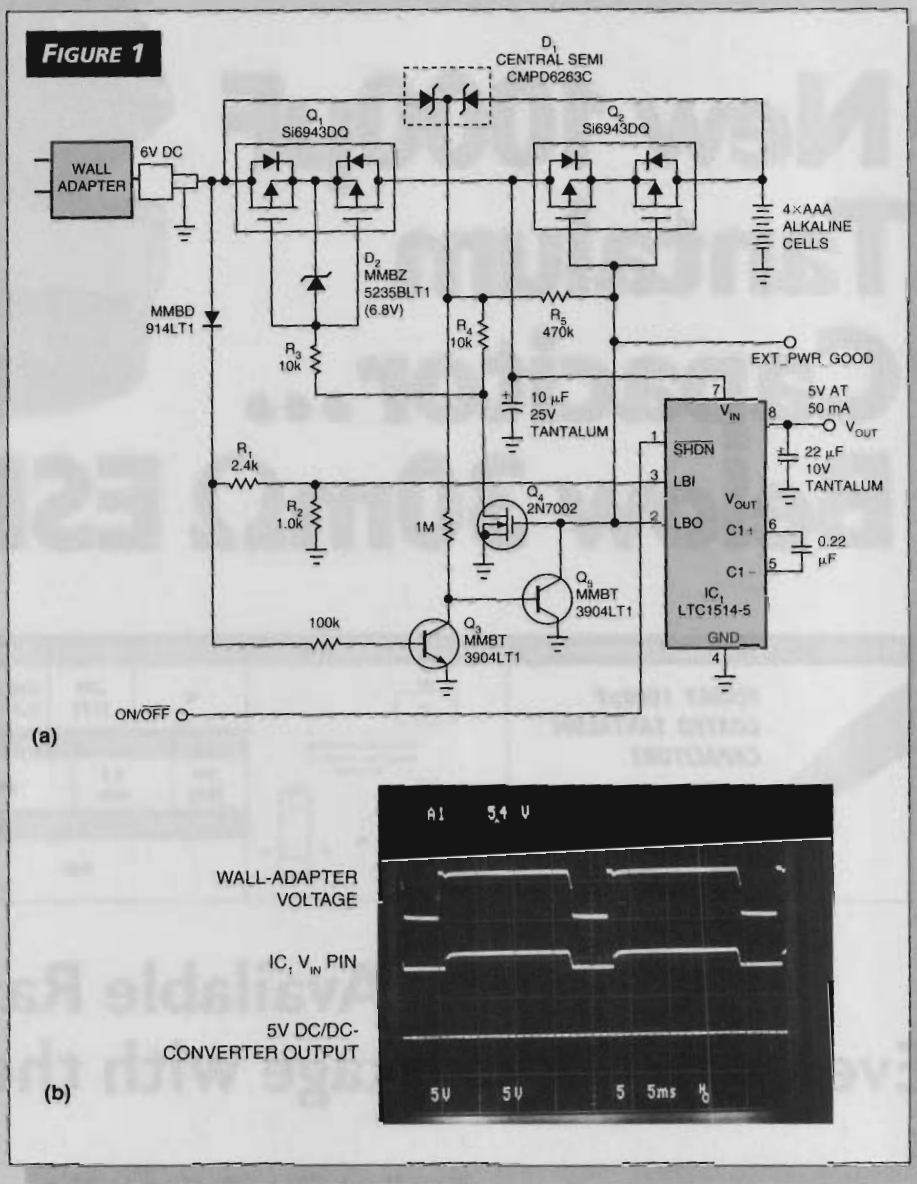
dc/dc conversion. Pulling SHDN low disables the 5V output, or you can connect SHDN directly to V_{IN}, pin 7, if shutdown is unnecessary.

Dual p-channel MOSFETs, Q_1 and Q_2, operate as input power switches to IC_1. The back-to-back MOSFET connection allows these power switches to block current in both directions, preventing conduction through the body diode. Depending on the operating mode, either Q_1 or Q_2 turns on to supply power to IC_1. **Figure 1b** shows the switch-over between the wall adapter and battery. The upper trace is the 6V wall-adapter voltage turning on and off; the middle trace is the input to IC_1, showing the voltage change between a 3.2V battery and a 6V wall adapter. The bottom trace is the output of the dc/dc converter delivering a constant 5V throughout the process.

Dual diode D_1 provides voltage to the MOSFET gates via R_3, R_4, and R_5. A comparator within IC_1 monitors the voltage on the LBI pin and releases the LBO output when the voltage on LBI goes above 1.145V. The R_1/R_2 voltage divider determines the external-power-good threshold, which is around 4.5V in this case. When the wall adapter is absent, the LBO pin is low. This low level forces the gates of Q_2 low, which puts Q_2 in a conducting mode, and keeps Q_4 off. With Q_4 off, R_3 and R_4 pull the gates of Q_1 high, which keeps Q_1 turned off. When the wall-adapter input voltage goes above 4.5V, LBO goes high, reversing the states of Q_1 and Q_2. The circuit includes Q_3 and Q_5 to hold the gates of Q_2 low when a wall adapter is absent. Without these transistors, Q_2 would never turn on when the user first installs batteries in the product, and IC_1 would forever be stranded without power.

Zener diode D_2 and R_3 prevent the design from exceeding Q_1's 8V $V_{GS(MAX)}$ rating with a high wall-adapter voltage of as much as 10V. **Figure 1a** indicates 5% values for R_1 and R_2; 5% is sufficient accuracy for setting the relatively noncritical threshold for switch-over from batteries to a wall adapter. All other resistors are assumed 1 or 2% accurate.

The entire circuit consumes very little pc-board area. IC_1 is a standard SO-8 footprint, and Q_1 and Q_2 are in the even smaller "micro" SO-8 package. All the remaining transistors and diodes are in SOT-23 packages.



A 5V-output step-up/step-down power supply (a) can smoothly switch between four alkaline cells and a 6V wall adapter. As the wall-adapter voltage turns on and off, from 0 to 6V, the output of the dc/dc converter delivers a constant 5V (b).

The circuit has the same efficiency as a linear regulator in step-down mode, yet it does something no linear regulator can do, which is boost the battery voltage. When the input voltage drops below approximately 5.2V, IC_1 switches to charge-pump doubler operation. This switch-over initially results in a big efficiency drop in IC_1—from approximately 90% to just less than 50%, according to the data sheet—but efficiency again improves as the input voltage drops. At an input voltage of 3.2V, IC_1's efficiency is approximately 80%. (DI #2220) EDN

To Vote For This Design, Circle No. 468

Four ICs implement video AGC and dc restore

TAMARA AHRENS AND MIKE WONG, ELANTEC SEMICONDUCTOR INC, MILPITAS, CA

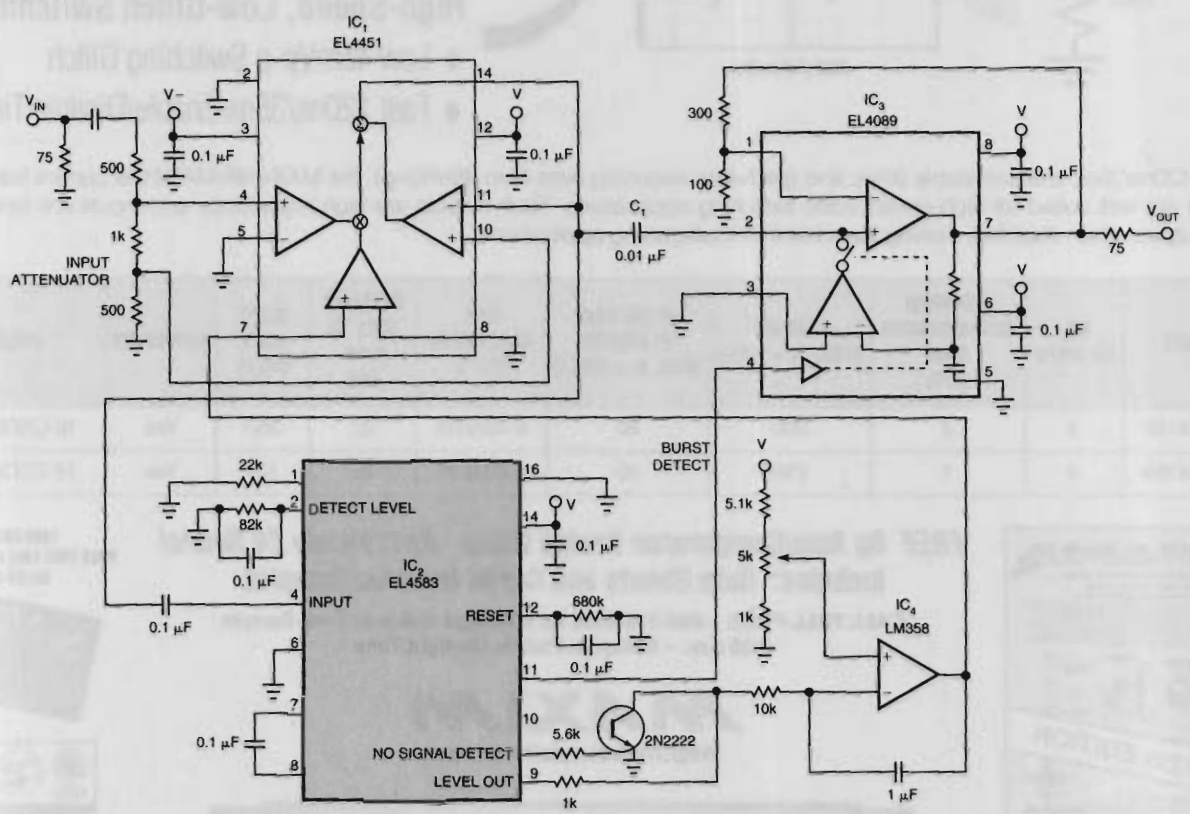
Four ICs—a multiplier, a sync separator, an op amp, and a dc-restore IC—along with a handful of passive components can implement a complete AGC and dc-restore circuit for video signals (**Figure 1**). The circuit consists of three main paths: the signal path, the gain-control path, and the dc-restore path. The input video signal first passes through an attenuator so that the circuit can handle oversized voltages. The attenuated signal drives IC_1, which multiplies this signal by the gain-control voltage. Both the gain-control and the dc-restore path use the output of the multiplier.

IC_2's sync separator recovers the timing-logic outputs of the video signal and also provides a level-out signal. This signal corresponds to twice the tip-to-porch voltage that the gain servo op-amp, IC_4, compares with a reference voltage of 0.7V, which is nominal for the NTSC standard. The integrated output of IC_4 drives the second input of multiplier IC_1. You can adjust the potentiometer for proper peak-to-peak amplitude through this servo system. In the event of a loss of signal, which pin 10 of the sync separator indicates, an npn transistor turns on, shunting the op amp's input to ground and sending the V_{GAIN} control signal to its maximum setting.

IC_2 also provides the dc-restore signal. The burst-detect output informs IC_3's dc-restore IC when to hold the previous value and when to restore the current output voltages. When the burst-detect signal is logic 1, the circuit stores the offset voltage on coupling capacitor C_1. Conversely, when a logic 0 appears at pin 4 of IC_3, the dc offset is null. You can reduce the value of C_1 to allow for compensation of larger correction voltages at the cost of greater droop during the hold time. IC_3 also contains an amplifier capable of driving back-terminated 75Ω cable.

Two passive components associated with IC_2 are critical.

FIGURE 1



This complete AGC and dc-restore circuit for video signals comprises a signal path, a gain-control path, and a dc-restore path.

The resistance on pin 2 determines the minimum signal level that the circuit can detect. A value of 82 kΩ allows IC_2 to detect signals greater than 100 mV at the sync tip. The other critical value is RESET at pin 12. This resistor sets the reference current and, subsequently, all the internal timing functions, for the entire chip. For NTSC video with a 15.7-kHz scan rate, a value of 681 kΩ with 1% tolerance is necessary. (DI #2221) EDN

To Vote For This Design, Circle No. 469

"Useless" masked μCs make useful PC peripherals

ALEC BATH, MOTOROLA INC, NORTHBROOK, IL

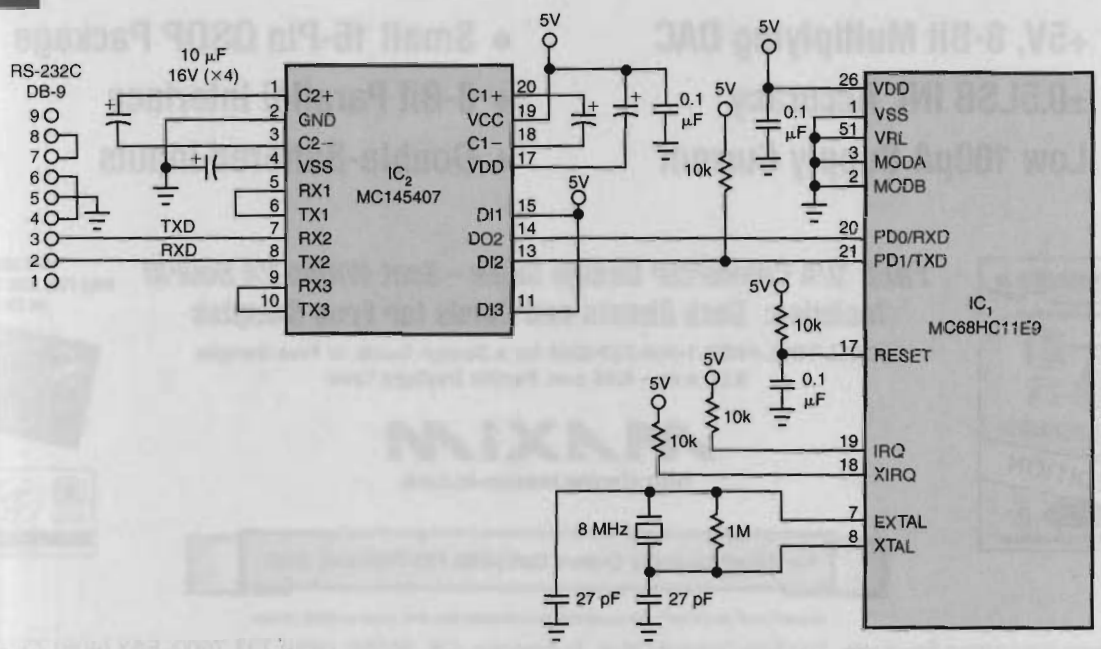
A software bug or a new code revision can often render hundreds of masked μCs all but useless for production purposes. However, by tapping into the 68HC11's bootstrap mode, you can attach these μCs to a PC's RS-232C serial port and put them to work. In the MC68HC11E9, 512 bytes of RAM are available for downloading a user's program. 512 bytes of EEPROM are also available to the programmer, as well as an 8-bit ADC, two serial ports, various timer functions, and many I/O ports. The masked-ROM locations are unused.

Figure 1 shows the connection from a 68HC11E9 (IC_1) to a PC's eight-pin RS-232C serial port. The HC11 resets into bootstrap mode, and a QuickBasic program downloads an S-record file at 1200 baud. Upon receipt of the final byte, the program executes at the start of RAM. IC_2 is a 5V-only RS-232C level converter. For proper communication synchronization, an 8-MHz crystal is necessary, although other crystal/baud-rate combinations are possible.

The QuickBasic program "bootload.bas" loads an assembled S-record file and strips the header, footer, and checksum information. The program then converts the ASCII text into raw hexadecimal data, adds a preamble $FF character for communications synchronization, and transmits the data at 1200 baud out COM port 1. The HC11's internal boot-loader-ROM program configures its SCI asynchronous serial port, looks for an $FF character, and downloads a program in RAM, starting at $0000. You can download the bootload.bas program from *EDN*'s Web site, www.ednmag.com. At the registered-user area, go into the Software Center to download the file from DI-SIG, #2222. (DI #2222) EDN

To Vote For This Design, Circle No. 470

FIGURE 1



By tapping into IC_1's bootstrap mode, you can attach the μC to a PC's RS-232C serial port and put the masked μC to work.

Use a printer port to record digital waveforms

DEAN SHEN, DYCAM INC, CHATSWORTH, CA

To record or capture special waveforms, those that appear once or have no fixed frequency, the usual technique is to use a logic analyzer or a storage oscilloscope. However, these tools are very expensive. Moreover, because of limited memory, a storage scope can record fewer than 1000 samples. The technique presented here provides an alternative method to recording digital waveforms. The idea is to use the PC's printer port to sample waveforms, and the PC's memory to store data. The large memory capacity of PCs allows you to store large samples. For example, 60 kbytes of memory can store 8×60,000=480,000 samples.

To sample data as fast as possible and to equalize sample periods, you use Debug directly to write an assembly program to implement the sampling procedure. Once the PC's memory stores the data, it is easy to display the waveform or to save it in a file. You use QBasic to display the waveform. To

LISTING 1–QBASIC ROUTINE FOR DISPLAYING WAVEFORMS

```
'72 is Up Scan Code
KEY 20, CHR$(0) + CHR$(72)
'73 is UpPg Scan Code
KEY 15, CHR$(0) + CHR$(73)
'80 is Down Scan Code
KEY 21, CHR$(0) + CHR$(80)
'81 is DnPg Scan Code
KEY 16, CHR$(0) + CHR$(81)
'75 is Left Scan Code
KEY 22, CHR$(0) + CHR$(75)
'77 is Right Scan Code
KEY 23, CHR$(0) + CHR$(77)
'1 is ESC Scan Code
KEY 17, CHR$(0) + CHR$(1)

ON KEY(15) GOSUB UpPage
ON KEY(16) GOSUB DownPage
ON KEY(20) GOSUB UpLine
ON KEY(21) GOSUB DownLine
ON KEY(22) GOSUB Left
ON KEY(23) GOSUB Right
ON KEY(17) GOSUB Finish

SCREEN 12
DEF SEG = &H40
DEF SEG = PEEK(&HFE) + 256 * PEEK(&HFF)
LINE (0, 4)-(639, 4)
FOR i% = 0 TO 32
 j% = i% * 19.5
 LINE (j%, 4)-(j%, 0)
NEXT i%

h% = 20
addr0% = &H180
fl% = 0
KEY(17) ON
WHILE fl% = 0

KEY(15) ON
KEY(16) ON
KEY(20) ON
KEY(21) ON
KEY(22) ON
KEY(23) ON

LOCATE 1, 40
PRINT (addr0% - &H180) / 80;
FOR i% = 0 TO 255
 FOR j% = 0 TO 128
 NEXT j%
NEXT i%
KEY(15) STOP
KEY(16) STOP
KEY(20) STOP
KEY(21) STOP
KEY(22) STOP
KEY(23) STOP

FOR i% = 0 TO 14
  y% = i% * 30 + 20
  addr% = addr0% + 80 * i%
  FOR j% = 0 TO 79
  x% = j% * 8
  SELECT CASE PEEK(addr% + j%)
  CASE 0
    IF j% > 0 THEN
      LINE -(x% - 1, y% + h%)
    END IF
      LINE (x%, y% + h)-(x% + 7, y% + h)
  CASE &HFF
    IF j% > 0 THEN
      LINE -(x% - 1, y%)
    END IF
      LINE (x%, y%)-(x% + 7, y%)
  CASE 1
    IF j% > 0 THEN
      LINE -(x% - 1, y% + h%)
    END IF
      LINE (x%, y% + h%)-(x% + 7, y% + h%)
      LINE -(x% + 7, y%)
  CASE 3
    IF j% > 0 THEN
      LINE -(x% - 1, y% + h%)
    END IF
      LINE (x%, y% + h%)-(x% + 6, y% + h%)
      LINE (x% + 6, y% + h%)-(x% + 6, y%)
      LINE -(x% + 7, y%)
  CASE 7
      LINE (x%, y% + h%)-(x% + 5, y% + h%)
      LINE (x% + 5, y% + h%)-(x% + 5, y%)
      LINE -(x% + 7, y%)
  CASE &HF
      LINE (x%, y% + h%)-(x% + 4, y% + h%)
      LINE (x% + 4, y% + h%)-(x% + 4, y%)
      LINE -(x% + 7, y%)
  CASE &H1F
      LINE (x%, y% + h%)-(x% + 3, y% + h%)
      LINE (x% + 3, y% + h%)-(x% + 3, y%)
      LINE -(x% + 7, y%)
  CASE &H3F
      LINE (x%, y% + h%)-(x% + 2, y% + h%)
      LINE (x% + 2, y% + h%)-(x% + 2, y%)
      LINE -(x% + 7, y%)
  CASE &H7F
      LINE (x%, y% + h%)-(x% + 1, y% + h%)
      LINE (x% + 1, y% + h%)-(x% + 1, y%)
      LINE -(x% + 7, y%)
   CASE &H80
     IF j% > 0 THEN
      LINE -(x%, y%)
     END IF
      LINE (x%, y%)-(x%, y% + h%)
      LINE -(x% + 7, y% + h%)
   CASE &H81
     IF j% > 0 THEN
      LINE -(x%, y%)
     END IF
      LINE (x%, y%)-(x%, y% + h%)
      LINE -(x% + 5, y% + h%)
      LINE -(x% + 5, y%)
      LINE -(x% + 7, y%)
   CASE &H83
     IF j% > 0 THEN
      LINE -(x%, y%)
     END IF
      LINE (x%, y%)-(x%, y% + h%)
      LINE -(x% + 6, y% + h%)
      LINE -(x% + 6, y%)
      LINE -(x% + 7, y%)
   CASE &HC0
      LINE (x%, y%)-(x% + 1, y%)
      LINE -(x% + 1, y% + h%)
      LINE -(x% + 7, y% + h%)
   CASE &HC1
      LINE (x%, y%)-(x% + 1, y%)
      LINE -(x% + 1, y% + h%)
      LINE -(x% + 6, y% + h%)
      LINE -(x% + 6, y%)
      LINE -(x% + 7, y%)
   CASE &HE0
      LINE (x%, y%)-(x% + 2, y%)
      LINE -(x% + 2, y% + h%)
      LINE -(x% + 7, y% + h%)
   CASE &HE1
      LINE (x%, y%)-(x% + 2, y%)
      LINE -(x% + 2, y% + h%)
      LINE -(x% + 6, y% + h%)
      LINE -(x% + 6, y%)
      LINE -(x% + 7, y%)
   CASE &HF0
      LINE (x%, y%)-(x% + 3, y%)
      LINE -(x% + 3, y% + h%)
      LINE -(x% + 7, y% + h%)
```

(continued on pg 138)

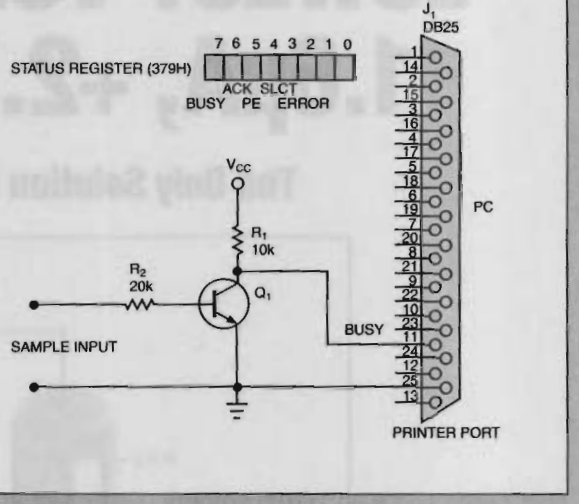
compare the recorded waveform and the waveform from a standard signal generator, you calculate the sample period. We have used the method successfully to record many different digital waveforms. **Figure 1** shows the sampling circuit. **Listing 2** gives the Debug sampling program. After execution, the routine saves the segment of recorded data in 40h:FEh.

The Basic program in **Listing 1** can easily access the data. This method uses a Dallas Semiconductor one-wire communications protocol. The PC is a 33-MHz 80486 machine; the sample period is approximately 2.03 µsec. The method shown here can record only one channel signal. However,

LISTING 1–QBASIC ROUTINE FOR DISPLAYING WAVEFORMS (CONTINUED)

```
    CASE &HF8
       LINE (x%, y%)-(x% + 4, y%)
       LINE -(x% + 4, y% + h%)
       LINE -(x% + 7, y% + h%)
    CASE &HFC
       LINE (x%, y%)-(x% + 5, y%)
       LINE -(x% + 5, y% + h%)
       LINE -(x% + 7, y% + h%)
    CASE &HFE
       LINE (x%, y%)-(x% + 6, y%)
       LINE -(x% + 6, y% + h%)
       LINE -(x% + 7, y% + h%)
    CASE ELSE
       LINE (x%, y%)-(x% + 7, y% + h%)
  PRINT addr0%
  END SELECT
 NEXT j%
NEXT i%
WEND

KEY(15) OFF
KEY(16) OFF
KEY(20) OFF
KEY(21) OFF
KEY(22) OFF
KEY(23) OFF
KEY(17) OFF

DEF SEG
END

UpLine:
 IF addr0% <= (&H3CE0 * 2) THEN
  CLS 1
  addr0% = addr0% + &H50
 END IF
RETURN

DownLine:
 IF addr0% > &H180 THEN
  CLS 1
  addr0% = addr0% - &H50
 END IF
RETURN

UpPage:
 IF addr0% <= (&H3CE0 * 2) THEN
  CLS 1
  addr0% = addr0% + &H460
 END IF
RETURN
DownPage:
 IF addr0% > &H5E0 THEN
  CLS 1
  addr0% = addr0% - &H460
 END IF
RETURN

Right:
 IF addr0% <= (&H3CE0 * 2) THEN
  CLS 1
  addr0% = addr0% - 1
 END IF
RETURN

Left:
 IF addr0% > &H180 THEN
  CLS 1
  addr0% = addr0% + 1
 END IF
RETURN

Finish:
 fl% = 1
RETURN
```

FIGURE 1



This simple circuit allows you to use your PC's printer port to record digital waveforms and to store them in memory.

LISTING 2–DEBUG ROUTINE FOR RECORDING WAVEFORMS

```
u100 13e
1358:0100 BA7903      MOV     DX,0379
1358:0103 EC          IN      AL,DX
1358:0104 2480        AND     AL,80
1358:0106 75FB        JNZ     0103
1358:0108 B900FD      MOV     CX,FD00
1358:010B BF8001      MOV     DI,0180
1358:010E 51          PUSH    CX
1358:010F B90800      MOV     CX,0008
1358:0112 51          PUSH    CX
1358:0113 EC          IN      AL,DX
1358:0114 90          NOP
1358:0115 90          NOP
1358:0116 D0E0        SHL     AL,1
1358:0118 D0D4        RCL     AH,1
1358:011A 59          POP     CX
1358:011B E21B        LOOP    0138
1358:011D 86E0        XCHG    AH,AL
1358:011F AA          STOSB
1358:0120 59          POP     CX
1358:0121 E2EB        LOOP    010E
1358:0123 8CDB        MOV     BX,DS
1358:0125 B84000      MOV     AX,0040
1358:0128 8EC0        MOV     ES,AX
1358:012A BFFE00      MOV     DI,00FE
1358:012D 89D8        MOV     AX,BX
1358:012F AB          STOSW
1358:0130 8EC3        MOV     ES,BX
1358:0132 BA00E0      MOV     DX,E000
1358:0135 CD27        INT     27
1358:0137 90          NOP
1358:0138 90          NOP
1358:0139 90          NOP
1358:013A 90          NOP
1358:013B 90          NOP
1358:013C 90          NOP
1358:013D EBD3        JMP     0112
```

you can easily modify the circuit and the sampling program to record two- and four-channel signals. You can download the executable Debug routine and the QBasic source code from *EDN*'s Web site, www.ednmag.com. At the registered-user area, go into the Software Center to download the files from DI-SIG, #2210. (DI #2210) EDN

To Vote For This Design, Circle No. 471